Trends In Hemodynamic Monitoring: A Review For Tertiary Care Providers

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Abstract

Ultrasound guided procedures for central line placement and for regional anesthesia is fast becoming a standard of practice. Transesophageal echocardiogram (TEE) is a method for monitoring hemodynamic status that utilizes the properties of ultrasound to visualize cardiac structures, assess global contractility, and estimate volume status. The effectiveness in using TEE in non-cardiac anesthesia settings is documented in the literature. Using TEE to guide interventions is not only applicable for use during anesthesia, but also as an adjunct to practice in critical care settings.

INTRODUCTION

A challenge to the United States (US) health care system is the graying of the population. As the population ages and requires more health care, a significant part of this care is in surgical services. Forty-percent of all surgeries are performed on patients 65 and older.1 Furthermore, more than half of the patients who are older than 65 will require surgery at least once during the remainder of their lives.1 Although operative mortality in the elderly has decreased in recent decades, perioperative, morbidity and mortality in elderly patients is still higher than in the younger populations. Therefore, the public's best interest lies in using those dollars as effectively as possible and continuing to find ways to reduce the incidence of perioperative complications. Surgical expenditures are expected to grow from $572 billion or 4.6% of the gross domestic product (GDP) in 2005, to $912 billion (in 2025 dollars) or 7.3% of the GDP.2 This projection is expected to represent 1/14 of the U.S. economy. One factor that has been found to have a significant influence on these expenditures is the increasing age of the population.2

Normal aging of the vascular system is associated with arterial stiffening and thickening, endothelial dysfunction, vascular cell changes, and increased systolic and pulse pressures. Similarly, normal aging of the heart is associated with increased left ventricular mass, increased myocardial stiffness, conduction system abnormalities, and diastolic dysfunction. These changes can lead to pathologic processes such as systolic hypertension, left ventricular hypertrophy, atrial fibrillation, coronary ischemia, and heart failure.3 In the elderly, the prevalence for cardiovascular disease is at least 30% for those aged 65 and older who present for surgery.4 This number does not include those with occult coronary disease.1

Both physiologic changes that occur with aging and the fact that the elderly are more likely to have co-morbid diseases increase their risk of morbidity and mortality. The elderly are also a high risk surgical patient because they respond to anesthetic medications differently than younger patients. This response is a result of a reduction in physiologic reserve of most organ systems. During periods of stress, such as surgery, that the reductions in reserve can become clinically significant.2

Occult hypovolemia commonly occurs during major surgery and is thought to result in impaired tissue perfusion, decreased oxygen delivery, and increased postoperative complications.5 A goal of anesthesia is hemodynamic optimization to ensure adequate organ perfusion.6 The elderly are the focus of research in hemodynamic optimization during non-cardiac surgery. Monitoring volume status and stroke volume have been shown to improve patient outcomes post-operatively and decrease hospital stay.5-8 Historically, monitoring tools such as central venous catheters (CVP) and pulmonary artery pressure catheters (PAC) have been used to determine fluid status and to guide interventions that promote hemodynamic optimization. In the past decade esophageal dopplers that measure stroke volume variation (SVV) have also been used.

LITERATURE REVIEW

CVP is an inaccurate predictor of intravascular volume during anesthesia due to cardiovascular changes during the intraoperative period and positive pressure ventilation.8 Despite available evidence, CVP is still commonly used to monitor trends and changes. PACs is an invasive catheter that is floated into the heart with or without the assistance of fluoroscopy. The use of PACs remains controversial due to complications associated with its placement and a lack of evidence showing improved clinical outcomes. Estimates suggest a mortality rate of 0.02% to 1.5% with placement of PACs.9

The traditional monitoring discussed demonstrate inadequacies in measuring volume status and assuring adequate tissue perfusion.5-10 Traditional invasive monitoring has also been linked with a 3-fold increase in major cardiac and noncardiac events. Complications that have been reported are myocardial infarction, pulmonary embolism, pulmonary edema, cerebral vascular accidents and bacterial pneumonia.5, 7, 8, 9 The Anesthesia Patient Safety Foundation and others have reported a high incidence of nosocomial infections associated with PAC and CVP catheters.11

In a single center, prospective, blinded, and controlled trial, 128 patients were randomized to groups who had fluid management guided by esophageal doppler or CVP monitoring. All patients were having colorectal surgery and had a mean age of 69.1 years. The results found that the patients who were monitored with an esophageal doppler had a median reduction in hospital stay of 1.5 days compared to those who were monitored with a CVP.6 In a systematic review, Abbas and Hill reported similar findings.5 Mahmood and other authors cited in this review stated that outcome data from esophageal doppler studies can be generalized to hypothesize possible outcomes that could be achieved utilizing TEE for hemodynamic monitoring.6,11 This generalization is possible due to the doppler technology. Both TEE and esophageal doppler utilize the use of ultrasound doppler that calculates stroke volume and ejection fraction.6-10

In a systematic review of the literature, Marik et al. examined techniques used to determine the intravascular volume in high risk patients.12 The authors found strategies used to guide fluid management actually can affect outcome. The review concluded that esophageal dopplers are useful clinical tools to predict fluid responsiveness but provide no information about ventricular function. Marik and colleagues also reported about 50% of unstable patients respond to a fluid challenge. The authors further discussed the added advantage of assessing global ventricular function in hemodynamically unstable patients, using bedside echocardiography for assessment of right and left ventricular function for management of critically ill patients.

TEE was developed in the 1970s and was used as a diagnostic tool by cardiologists. Since the 1990s, TEE has gained acceptance as a monitoring tool during cardiac surgery, related to its ability to directly visualize cardiac structures and determine volume status. The effectiveness of the TEE as a clinical monitor to assist in the hemodynamic management of patients during general anesthesia and reliability to make intraoperative diagnosis in emergency situations has been well established.11 The use of TEE as a clinical monitor is gradually expanding to and now being used during other high risk surgeries such as neurosurgeries, thoracic and vascular surgeries, extensive abdominal surgeries, transplantation, and hip surgeries.9 Patient populations discussed in the literature that would benefit from TEE monitoring include those at risk for post-operative renal and hepatic failure. Patients who are at risk for post-operative renal and hepatic failure are those who have a history of unstable angina, heart failure, aortic stenosis, ejection fraction less than 30%; patients with pulmonary hypertension; and those individuals who are older than 65 years of age with co-morbidities.9

TEE provides real-time noninvasive monitoring of high risk patients and avoids the morbidity and mortality associated with more invasive methods. In addition, TEE affords the practitioner reliable cardiac filling volumes based on direct left ventricular assessment compared to CVP/PAC data derived from indirect right ventricular and pulmonary artery occlusion pressures.9 Three assessment parameters TEE assesses are global contractility, the presence of regional wall motion abnormalities, and the first indication of volume status.10

TEE provides an accurate assessment of left ventricular preload and can be used dynamically to follow the response to fluid resuscitation during non-cardiac surgery. Studies comparing right ventricular volume using right ejection fraction by means of a PAC to assessments of left ventricular volume by TEE found that the PAC overestimated left ventricular preload.9, 11 This overestimate can cause a false sense of security during volume resuscitation in hypovolemic patients especially when hypovolemia is due to trauma. The study found a positive relationship with automatic border detection with TEE and left ventricular preload. The estimate of automatic border detection is not

affected by artifact from positive pressure ventilation which may influence right heart measurements; that is, CVP and PAC.9, 10, 11

Complications that occur with TEE assessments are mostly in the outpatient population with a patient who is under moderate sedation. These complications are associated with inadequate levels of sedation, difficulty swallowing the probe, and reactions to topical anesthetic.8, 11 In a retrospective case series of 7,200 adult patients who were managed with TEE during cardiac surgery, the overall morbidity was 0.20% with a mortality of 0%. Dental injury and gastrointestinal hemorrhage were estimated at 0.03% along with dislodgement of the endotracheal tube. Perforation of the esophagus represented 0.01% of the population studied.11 Esophageal injury is evident as soon as 24 hours after the use of TEE, but could present up to 8 days later.11 Contraindications to using TEE are esophageal injury or stricture, recent esophageal or upper gastric surgery, known compression of esophagus, esophageal varices, and gastro-intestinal bleeding.8, 11

EVIDENCE

Limited studies exist that explore patient outcomes using TEE in the non-cardiac surgery setting. The lack of research data is believed to be associated with the limited number of practitioners who have been educated in interpreting TEE.13, 14 Cabrera and Hofer conducted prospective studies using TEE for patient management during non-cardiac surgery.13, 14 The studies were conducted at single institutions with a patient sample size of n = 98 and 99 respectively. Patients in the Cabrera study were undergoing large abdominal operations. Hofer included vascular and thoracic procedures also. All participants were above the age of 65 and had a history of cardiac disease. A TEE assessment was performed on each patient. Interventions performed reflected the results of the TEE evaluations. Both researchers identified cardiac anomalies in the study participants not previously diagnosed. Cabrera identified 2 patients who were not at high risk for post-operative complications and were excluded from the study.13

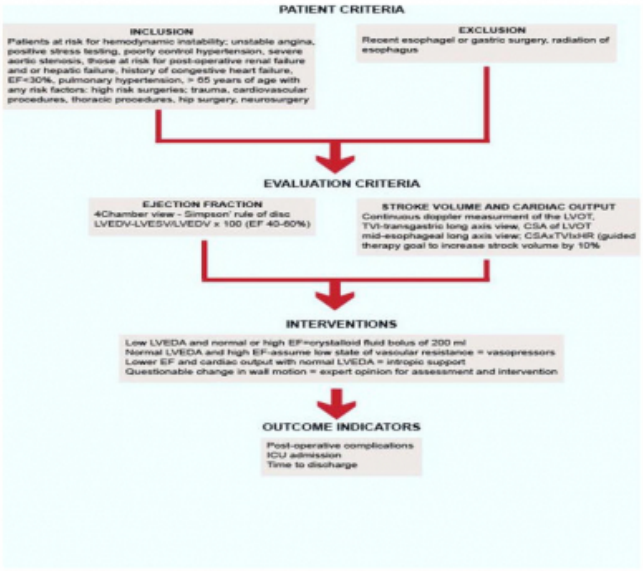
Hofer's study focused on intraoperative management using TEE evaluation. Based on the TEE findings, changes in drug therapy were made in 47%; 24% received fluid challenges. The evaluations resulted in the decision to use vasodilators or vasopressors. The authors concluded that TEE had a significant impact on the guidance of care.14

Cabrera also used TEE monitoring throughout the surgery. The study participants were divided into groups; those who received intraoperative management changes, changes in post-operative management, and TEE used in place of PAC. The authors reported that 48% of the patients had changes in intraoperative management based on TEE findings, 25% had changes in post-operative management (intensive care vs. post anesthesia care unit), and 24% had PAC placed post-operatively for further management.13 Both studies concluded that TEE was an effective assessment tool to identify clinical findings that influence care.13, 14 Neither, Cabrera or Hofer discussed if TEE resulted in shorter discharge time from the hospital when compared to similar surgeries.

An algorithm has been constructed (Figure 1) to demonstrate how a practitioner could utilize TEE in the management of high risk patients. First, it is important to identify patients who are at risk for systemic complications. The use of TEE to evaluate ventricular function (stroke volume and ejection fraction) can guide decisions in care. Further assessment with TEE would evaluate the effectiveness of prescribed care.

Figure 1

Utilization of TEE in Patient Management



Criteria adapted from: Abbas & Hill[5]; Dark[7]; D'Angelo & Dutton[8]; Rose [11]; Cabrera[13]; and Hofer.[14]

Sudden cardiac arrest in non-cardiac surgery is rare but can have catastrophic consequences. In a prospectively collected case series of 125,965 patients, 10 of these patients suffered from a cardiac arrest during non-cardiac surgery.15 In the 10 patients, TEE was able to detect abnormalities in 9 of these patients. TEE diagnosed myocardial infarctions in 5, pulmonary embolism in 2, hypovolemia in 1, cardiac arrhythmia in another and in the final patient no cardiac pathology was found. Of these 10 patients, 7 survived; the

other 3 had the following: 1 with myocardial infarction, 1 with severe internal bleeding, and 1 died of an unknown cause.15

PRACTICE IMPLICATIONS

Advanced knowledge is needed to provide appropriate interventions in the intensive care unit (ICU) or during anesthesia for high risk populations, specifically the elderly with cardiac disease. One would assume that knowledge of how aging affects the cardiovascular system is sufficient information for advanced practice nurses (APN) to guide interventions. No scientific evidence exists to support such a concept even though it is logical that knowledge of the physiology of the aging can help the APN avoid management pitfalls and detect problems more rapidly before they progress to more serious problems.6

In 2011, the Institute of Medicine (IOM) published recommendations for nursing (The Future of Nursing: Leading Change, Advancing Health).17 Suggested recommendations for nursing include: strengthening nurse education and training, enabling nurses to practice to the full extent of their education and training, and advancing inter-professional collaboration to ensure coordinated and improve patient care. Knowledge of TEE assessment and the ability to assess hemodynamically unstable situations further expands APN practice. Ultrasound has become a vital tool for the diagnosis of clinical findings, and has become an adjunct in care for patients in the ICU and during anesthesia. APNs have crucial roles in these settings. TEE provides direct information about cardiac function. This information can be used to guide appropriate interventions for the patient. TEE provides the APN with an effective technological tool in assessing, implementing, and evaluating care.

For APNs, the knowledge of TEE assessment can improve patient care by enhancing collaborative practice. The APN who has the ability to interpret TEE has a further means to be an active collaborator in the care of the patient. The ability to interpret and discuss findings of a TEE evaluation gives the APN a basis to discuss and implement appropriate care which reflects the clinical findings for each patient. By using TEE, the practitioner can effectively evaluate interventions and modify care appropriately. Information and knowledge that improves inter-professional communication and coordination of patient care will in turn foster patient care improvement.

In summary, the utilization of TEE as a hemodynamic monitor can be used as an effective measure of hemodynamic stability. Educating providers, including certified registered nurse anesthetists (CRNAs) and acute care nurse practitioners, in the use of TEE can increase knowledge related to hemodynamic monitoring. Populations that are at high risk for hemodynamic instability in critical care and during anesthesia could benefit from use of this technology to improve care. Staying current in technology use which can affect patient outcomes is essential for all health care providers.

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